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(54) **Optical determination of the relative positions of objects in space**

(57) The equipment of optical determination of relative positions of at least two objects (R) such as vehicle wheels, is made up of two optical determination systems (12;14) of an objects relative position in space, each in relation to its observation marker (Cl2, Cl4). An optical system of reference (12) is made up of an aim (26) visible from the other optical system (14) during the absence of the objects (R). The other optical system (14) will be made up of means (20) of analysis of an image of the aim (26) and means (20) of positioning of the aim (26) in relation to its observation marker (Cl4), in order to deduce the position of the observation marker (Cl4) of the other optical system (14) in relation to the observation marker (Cl2) of the optical system of reference, from the positions of the aim (26) in relation to the observation marker (Cl4), and of the aim (28) in relation to the observation marker (Cl2) of the optical system of reference (12).
Application to a vehicle's geometry control.

FIG.I

Description

- [0001] This invention concerns an equipment of optical determination of relative positions of at least two objects in space, of the type made up of at least two optical systems, each associated to an observation marker, the optical systems each being adapted for the determination of an object's position in space, in relation to its observation marker; from an image of the object collected by the aforesaid optical system..
- [0002] It moreover concerns a process of optical determination of relative positions of at least two objects in space, of the type making use of at least two optical systems each associated to an observation marker, (the optical systems each being adapted for the determination of an object's position in space, in relation to its observation marker, from an image of the object collected by the aforesaid optical system..

- [0003] For a vehicle's geometry control, it is necessary to know the relative positions of the vehicle's wheels. This data allows to control and possibly correct the wheel alignment and in particular the vehicle's geometry.
- [0004] For this purpose, different equipments and procedures are known, allowing, with the help of several optical systems, each observing a wheel of the vehicle, he determination of the relative positions of these wheels. Such mechanisms and procedures are described for instance in the documents WO-94/05969 and US-A-5,675,515.
- [0005] In these equipments the optical systems are made up of independent cameras, or a sole camera, combined with sets of lenses defining distinct optical routes of a same incident ray. The optical systems allow simultaneous observation of the vehicle's wheels, and, from the wheels images, to determine their relative positions.
- [0006] For this purpose, it is necessary for the different optical systems to be in known relative positions, otherwise it is impossible to correlate the data obtained from the images of each wheel. In order to guarantee stable relative positions of the optical systems, the ones with respect to the others, the mechanisms described in these documents provide fixed mechanical structures on which the optical systems are immobilized.
- [0007] The presence of such fixed mechanical structures makes the equipment bulky. Moreover, it is fragile since the distortion, for instance following an involuntary shock, of the fixed mechanical structures leads to disproportioned errors of the vehicle wheel's relative positions.
- [0008] The invention intends to offer equipment and procedures for the optical determination of relative positions, in space, of at least two objects, more particularly of the vehicle's wheels, the equipment having reduced dimensions, being easy to use, and having reduced sensitivity to harsh conditions found in a garage.
- [0009] For this purpose, the invention intends to offer an equipment and procedure of optical determination of relative positions, in space, of at least two objects, mentioned above, characterized by the mobility of optical systems the ones with respect to the others, by the fact that an optical system, forming an optical system of reference, is made up of a set of points of reference, of known geometrical configuration, the set of reference points being immobilized in a known position in relation to the optical system of reference's observation marker, and visible the or each other optical system in the absence of the objects, by the fact that the or each other optical system includes means of analysis of an image of the set of reference points and means of positioning of the set of reference points in relation to its observation marker, and by the fact that it includes means of deduction of the position of the observation marker of the or each other optical system in relation with the optical system's

observation marker, from the position of the set of reference points in relation to each observation marker, and the known position of the set of reference points in relation to the observation marker of the optical system of reference.

- [0010] Following characteristic methods of realization, the optical equipment is made up of one or several of the following characteristics: - each optical system includes a video camera held up by a tripod and linked to a common data processing central unit ; - the aforesaid set of reference points is made up of a group of discreet visible coplanar markers as well as at least one visible non coplanar marker. ; - it's made up of brackets fitted to each be linked to an object in a known position, and so that each optical system includes means of determination of the position of a bracket in space with respect to its observation marker, means of deduction of the object's position in respect to its observation marker from the bracket's determined position with respect to its observation marker and of the known position of the bracket with respect to the object. - the equipment including four optical systems intended to be approximately set out at the vertexes of a quadrilateral for the determination of the relative positions of four objects in space, the objects being set out inside the zone delimited by the quadrilateral; it includes two pieces of optical equipments such as defined above, the set of reference points of a first optical system of reference being visible from the second optical reference system, in the absence of objects, the second optical system of reference includes means of analysis of an image of the set of reference points of the first optical system of reference and means of positioning of the set of reference points in relation to its observation marker; it includes means of deduction of the position of the observation marker of the second optical system of reference, from the position of the set of reference points of the first optical system of reference with respect to the observation marker of the second optical system of reference, and from the known position of the set of reference points of the first optical system of reference with respect to the observation marker of the first optical system of reference and it includes means of deduction of the observation marker's relative positions of each optical system.
- [0011] Besides, the invention has the purpose of an optical method of determination of the relative positions of at least two objects in space, of the type aforementioned, characterized by the fact that the optical systems are mobile the ones with reference to the others, and that an optical system, forming an optical system of reference is equipped with a set of reference points, of known geometrical configuration, the set of reference points being immobilized in a known position with respect to the optical system of reference's observation marker, and visible from the or each other optical system in the absence of the objects, that the or each of the optical system analyses an image of the set of reference points and determines the

positioning of the set of reference points with respect to its observation marker, that the position of the observation marker of the or each optical system with respect to the optical system of reference's observation marker, can be deduced from the position of the set of reference points with respect to each observation marker, and from the known position of the set.

- [0012] The invention will be better understood after reading the following, given only as an example and in reference to the sketches, as so :

- Figure 1 is a top view of an optical equipment following the invention adapted to determine the relative positions of the four wheels of an automobile ;
- Figures 2A et 2B are perspective views of a common optical system of reference of the device of figure 1 on which are respectively represented an observation marker to the image collecting gear and a visible marker defined by a set of reference points,
- Figure 3 is a view in perspective of an optical system of reference placed in front of a mirror, which is mobile between two positions, in order to determine the position of the observation marker of the optical system with respect to its visible marker, and
- Figure 4 is a diagrammatic view illustrating the determination following the invention of the relative positions of the observation markers of the two opposite optical systems.

- [0013] The equipment pictured on figure 1 is meant to determine, in an optical way, the relative positions of the four wheels R of an automobile indicated by reference 10.
- [0014] The equipment is made up of four optical systems 12, 14, 16, 18 associated each to a wheel R of the vehicle. Each of them includes a CDD video camera marked 12A, 14A, 16A. 18A. These four cameras are connected to a central data processing unit 20 made for instance by a computer set up to handle the incoming images.
- [0015] The optical systems 12, 14, 16, 18 are mobile with respect to each other around the vehicle 10. For a correct operation , the optical systems are arranged still at the four vertexes of a quadrilateral, more particularly a rectangle surrounding the vehicle.
- [0016] The optical system 12 is represented in perspective in figures 2A and 2B. The video camera 12A is supported by a tripod 24 suitable to be placed on the floor. Moreover, the camera 12A is integral with an aim 26 defining a visible marker (0,xyz) marked A12, and visible on figure 2A. The aim 26 is brought to a standstill by mechanical means with respect to the camera structure and more particularly with respect to its observation marker (0'x'y'z') marked Cl2. The observation marker Cl2 is connected to the camera 12A 's image collecting component 28 and more particularly to its CCD sensor.

- [0017] The optical system 12 forms an optical system of reference. In the same way, the optical system 16, set out in the opposite corner with respect to the vehicle in the configuration of figure 1, forms also an optical system of reference and has a structure identical the one of the optical system 12.
- [0018] On the contrary, the optical systems 14 and 18 are devoided of aim and include an ordinary video camera 14A, 18A supported by a tripod.
- [0019] In variation, the optical systems 14 et 18 have the same structure as the optical systems 12 and 16. In that case, the four optical systems are optical systems of reference , which allows redundant measurements and therefore a higher reliability of those measurement results.
- [0020] As represented in figure 2A, the aim 26 is made up, for instance, by a disk with an axis O. Twelve coplanar points are distributed on its circumference 26A..Furthermore, the aim 26 includes a thirteenth point 26B set out in front of the main plane of the disk containing the twelve points 26A.
- [0021] This point particularizes the disk 26 angularly and allows to define two orthogonal axis, Ox and Oy in the plane of the aim. The axis Oy runs advantageously at point 26B.
- [0022] The aim 26 shows a principal axis of symmetry, defined by the twelve coplanar points regularly distributed on the circumference of the disk. The main axis of symmetry forms an Oz axis perpendicular to the axis Ox, Oy.
- [0023] The axis Oz, Oy, Oz and the point O define the visible marker A12.
- [0024] That way, the aim 26 forms a set of reference points, of known geometrical configuration, defining the visible marker A12. The former is brought to a standstill in a position that can be determined with respect to the observation marker C12 of the camera.
- [0025] As represented on figure 28, the observation marker C12 has for axis, marked O', the axis of the CCD sensor of the camera 12A. The observation marker is defined by a trihedron (CTX', oy, O'z'), where O'z' is the optical axis of the camera, O'x' is an axis parallel to the CDD sensor's horizontal lines of pixels and is an axis parallel to the vertical columns of pixels of the CCD sensor.
- [0026] The geometrical configuration of the set of points of reference of the aim 26 is memorized in the data processing unit 20.
- [0027] The data processing unit 20 can bring into operation algorithms determining the position of an object in space. In particular, it is adjusted in order to determine the position of an object holding a set of reference points set up according to a known geometrical configuration, this configuration having first been memorized in the unit 20. This position is determined after the image of this object taken by a camera connected to the data processing

unit. The position of the object in space is calculated with respect to the observation marker Cl2 of the camera. The algorithm brought into operation is of all adapted types and for example of the type described in the application WO 94/05969.

- [0028] In order to bring into operation such algorithms, it is advisable to use cameras that have been standardized beforehand to compensate for errors resulting from imperfections of the camera and its included sensor.
- [0029] For this purpose, we determine, for each camera, its intrinsic characteristics (observation marker, focal distance, size of image elements or pixels, radial distortion, tangential distortion) and its extrinsic characteristics (rotation and translation which, applied to the observed object, form an image strictly identical to the image observed by the camera cleared of its distortions). In that way we determine by known methods the corrections that have to be brought to the produced images in order to determine a correct position of an object in space.
- [0030] In order to bring the method into operation following the invention, it is necessary to know, for each optical system of reference 12, 16, the relative positions of the observation marker of the camera, and of the visible marker defined by the aim. In fact, it is extremely tricky, or even impossible, during the immobilization of the aim on the camera , to fasten the latter so that the two markers Cl2 et Al2 merge exactly.-
- [0031] Figure 3 shows the method brought into operation to determine the relative position of the two markers C12 and A12 characteristic to the optical system 12. The method used for the optical system 16 is similar.
- [0032] After this method, the optical system 12 is set out opposite to the reflecting side of a plane mirror 50. This mirror is hung onto a support 52. The means of suspension are adjusted to allow the free rotational movement of the mirror around a vertical axis Δ
- [0033] On its reflecting side the mirror 50 includes a set of reference markers 54A made up of black disks distributed, in a known geometrical figure such as a square, at the circumference of the mirror. An additional reference marker 54B is set up in front of the reflecting side of the mirror 50. The geometrical configuration of the reference markers 54A et 54B is known and memorized in the data processing unit 20.
- [0034] On figure 3, the normal to the mirror 50 is marked n. This normal is perpendicular to the mirror and runs through the center of the figure defined by the set of markers 54A et 54B. The mirror includes its own marker (Om, XmYmZm) of which the center Om is the center of the figure defined by the markers 54A. The axis OmZm runs after the normal n. The axis OmXm and OmYm run perpendicularly one to the other in the plane of the mirror 50. Advantageously the axis OmYm runs parallel to the axis Δ

- [0035] The aim 26, bearing the set of reference points 26A and 26B, is thrown back on the reflecting surface of the mirror 50 and forms an image of the aim marked 56 on the mirror.
- [0036] In that way, the camera 12A collects, in the observation marker C12, an image of the reflecting side of the mirror 50 including on one hand the set of reference markers 54A and 54B, and on the other hand, the reflected image 56 of the aim supported by the optical system.
- [0037] The camera 12A connected to the data processing unit 20 defines, from the memorized algorithm, the position of the mirror 50 with respect to the observation marker C12, using the image taken from the set of reference markers 54A and 54B supported by the mirror.
- [0038] In the same way, the data processing unit 20 defines, by bringing into operation the memorized algorithm, the position of the virtual image of the aim 28 with respect to the observation marker C12 of the camera. More precisely, the data processing unit 20 defines the position of a visible virtual marker (O", x"y"z") associated to the virtual image 26 with respect to the observation marker (O'x'y'z') of the camera.
- [0039] The visible virtual marker (O", x"y"z") is the virtual image of the visible marker (O,xyz) obtained by reflection in the mirror 50.
- [0040] From the relative positions, of the observation marker (O', x'y'z') with respect to the mirror's marker (Om ,XmYmZm) on one hand, and of the visible virtual marker (0"x"y"z") with respect to the observation marker (0',x'y'z') on the other hand, the data processing unit 20 defines the position of the observation marker (0', x'y'z') of the camera, in relation to the visible marker (0,xyz) defined by the aim 26.
- [0041] For this purpose, the data processing unit 20 proceeds as follows.
- [0042] With the algorithm brought into operation by the unit 20, the position of the virtual image, corresponding to the image 56 of the aim and obtained by reflection into the mirror 50 is defined by analysis of the image collected by the camera 12A
- [0043] This positioning allows the definition of a matrix Mo-v running through the virtual marker (0",x"y"z") connected to the virtual image and the observation marker (O',x'y'z'). This change of markers expresses itself in a matrix form as follows :

$$\begin{bmatrix} x'' \\ y'' \\ z'' \\ 1 \end{bmatrix} = M_{o\text{-}v} \begin{bmatrix} x' \\ y' \\ z' \\ 1 \end{bmatrix} \text{ où } M_{o\text{-}v} = \begin{bmatrix} R & T \\ 0 & 1 \end{bmatrix}:$$

Mo-v being a 4x4 matrix.

where R is a 3x3 subset matrix of rotation

T is a 1x3 subset matrix of translation

(x",y",z") are the coordinates of a point M visible virtual marker (O",x"y"z") ; and

(x',y',z') are the coordinates of a point M in the observation marker (O',x'y'z').

- [0044] With an algorithm of the same kind, the data processing unit 20 defines the position of the mirror 50, and more precisely of its associated marker (Om, Xm Ym Zm) in the observation marker (O',x'y'z') connected to the camera. To realize this, the data processing unit 20 analyses the image of the mirror 50 collected by the camera and defines the position of the mirror 50 from the analysis of the position of the reference markers 54A and 54B appearing on the image.
- [0045] A crossing matrix Mm, between the observation marker(O', x'y'z') and the marker (Om,Xm YmZm) of the mirror, is defined in that way. The coordinates of a same point M in the two markers are consequently bound by the relation :

$$\begin{bmatrix} x_m \\ y_m \\ z_m \\ 1 \end{bmatrix} = M_m \begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix} \text{ où } M_m = \begin{bmatrix} R_m & T_m \\ 0 & 1 \end{bmatrix}$$

(1)

with Rm being a 3x3 subset matrix of rotation

Tm, is a 1x3 subset matrix of translation; and

(Xm Ym Zm) are the coordinates of the point M in the marker of the mirror (Om,XmYmZm)

from which we deduce :

$$\begin{bmatrix} x' \\ y' \\ z' \\ 1 \end{bmatrix} = M_m^{-1} \begin{bmatrix} x_m \\ y_m \\ z_m \\ 1 \end{bmatrix}$$

where Mm-1 is the inverse of the matrix Mm

- [0046] In that way, it is possible to express, in the visible virtual marker (O",x"y"z") the coordinates of the point M according to its coordinates in mirror marker (Om,XmYmZm) with the following matrix relation :

$$\begin{bmatrix} x'' \\ y'' \\ z'' \\ 1 \end{bmatrix} = M_{o'-v} \begin{bmatrix} x_m \\ y_m \\ z_m \\ 1 \end{bmatrix}$$

- [0047] In order to define the position of a real point M in the marker of the mirror (Om,XmYmZm), we use the property according to which the virtual image of a point of coordinates (x,y,z) in a given marker, when the mirror extends after the plane Ox, Oy, has for coordinates (x,y, z).
- [0048] In that way, the coordinates (x",y",z") of the virtual image in the visible virtual marker of the point M of coordinates (x,y,z) in the visible marker are obtained with the application of the following diagonal matrix Sz :

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

- [0049] The coordinates (xyz) of a point M expressed in the visible marker (O,xyz) express themselves according to the coordinates (XmYmZm) of this same point in the marker of the mirror (Om XmYmZm), as follows :

$$\begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix} = M_{o'-v} * S_z \begin{bmatrix} x_m \\ y_m \\ z_m \\ 1 \end{bmatrix}$$

In writing Mo'= Mo-v'*Sz. Consequently Mo' is the crossing matrix of the mirror marker (Om XmYmZm) at the visible marker (O,xyz).

- [0050] In order to define the coordinates of a point in the visible marker (0,xyz) from the coordinates (x',y',z') of the same point in the observation marker (O,x'y'z'), we deduce from the relations (1) and (2) the following matrix relation :

$$\begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix} = M_o \begin{bmatrix} x' \\ y' \\ z' \\ 1 \end{bmatrix}$$

$$M_o = M_{o'} * M_m^{-1} * S_z * M_m$$

- [0051] In that way, we understand that the central data processing unit 20 can, by using the calculation above, define the position of the observation marker Cl2 associated to the camera with respect to the visible marker A12 associated to the aim 26 interdependent with this camera.
- [0052] Moreover, following the invention, it is planned to position the whole set of optical systems, and more precisely the optical systems of reference with respect to the vertical of the place of control of the vehicle.
- [0053] For this purpose, we define an image of the mirror 50 in its first position, represented with thick strokes on figure 3. We then move the mirror to a second position represented with joined strokes on figure 3. The shifting is carried out around the mirror's suspension axis Δ. This axis Δ corresponds to a vertical of the equipment's place of operation.
- [0054] From the memorized algorithm, the central data processing unit 20 defines, for the two positions of the mirror, the coordinates of the planes in which the mirror stretches out. The line Δ corresponds to the intersection of the two planes defined in this way. In this way, the central data processing unit 20 defines the relative position of the optical system of

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reference with respect to a group of horizontal planes which are of primary importance for the particular case of vehicle geometry.

- [0055] On figure 4, the opposite optical systems 12 and 14 are represented diagrammatically, in the absence of the automobile 10. The optical systems 12 and 14 are set out, as in figure 1, one facing the other with a sufficient space to allow the vehicle 10 to pass through.
- [0056] In order to define for instance the relative position of the vehicle's front wheels, the relative positions of the observation markers associated to the optical systems 12 and 14 have to be defined. The former are represented on figure 6 by Cl2 and Cl4.
- [0057] The crossing matrix between the observation marker Cl2 and the visible marker Al2 is known since it has been defined following the previously described method.
- [0058] In order to determine the relative positions of the observation markers Cl2 and Cl4, the optical system 14 produces, under the command of the data processing unit 20 an image of the aim 26. This image is processed by the data processing unit 20.
- [0059] This unit, knowing the geometrical configuration of the set of points of reference of the aim 26, defines, by using the memorized algorithm, the relative position of the aim 26 with respect to the observation marker Cl4 of the observing optical system. In that way it deduces the position of the visible marker Al2 defined by the aim 26 with respect to the observation marker Cl4.
- [0060] Knowing the crossing matrix of the observation marker Cl2 at the visible marker A12 and vice versa, the central data processing unit 20 determines the relative positions of the observation markers C12 and Cl4.
- [0061] In that way, the central data processing unit 20 determines the relative position between the observation markers at the two opposite optical systems 12 and 14.
- [0062] In the same way, the optical system 16 set out on the opposite side of the optical system 12 with respect to the location of the vehicle 10 observes the aim 26 supported by the optical system12 in the absence of a vehicle. In the same way the data processing unit 20 determines the position of the observation marker, written Cl6, associated to the optical system 16 with respect to the observation marker C12 of the optical system of reference.
- [0063] Finally, the optical system 16 is also equipped with an aim, immobilized in relation to the camera inserted in this optical system , the observation of the former with the optical system 18 allows the central data processing unit 20 to determine the position of the observation marker, marked Cl8 associated to the optical systems 16 with respect to the observation marker Cl6 of the optical system of reference 16.

- [0064] In fact, with a procedure similar to the one described opposite to figure 4, the knowledge of the relative positions of the visible marker of the aim, supported by the optical system 16 and of the observation aim associated with the optical system 16, allow the determination of the relative positions of the observation markers C16 and C18.
- [0065] And that way, by chaining, if an optical system is called of reference , the whole equipment is bearing a reference.
- [0066] After positioning the vehicle 10, the four optical reference systems can't observe each other any more. Nevertheless, each of them is capable of taking an image of a wheel R of the vehicle.
- [0067] As described in the application WO-94/05969, each wheel is equipped with an aim or bracket 60 connected rigidly and in a known manner to the wheel. Each bracket includes a set of markers arranged after a geometrical configuration known and memorized in the data processing unit 20.
- [0068] Prior to determining the relative positions of the brackets and consequently of the wheels, it is advisable to take in account the buckle of each bracket and its off-centering in order for the central data processing unit 20 to take it into account for further calculations. For this purpose, and following a method known per se, the unit 20 analyses several images of each wheel taken in distinct determined positions.
- [0069] From the simultaneous observation of each bracket 60 from the four optical systems, the central data processing unit 20 determines the relative position of each wheel with respect to the observation marker of the camera associated as known per se. In fact, the center of the wheels being known, the horizontal planes being known, their point of section with the plan of the wheels being known, the vertical of the place being known, it is easy to find 16 angles and the characteristic distances of the vehicle's geometry.
- [0070] Knowing the relative positions of the observation markers of the four optical systems, the central data processing unit 20 deduces the relative positions of the vehicle's four wheels, and so it is possible to determine the vehicle's geometry and to realize all adjusting procedures necessary to a satisfactory operation of the vehicle..
- [0071] It is understood that with such an equipment, the position of the four optical systems can be modified for each vehicle. Moreover, it is not necessary between each measuring operation to keep a fixed position between the optical systems. It is sufficient that between each vehicle, the unit 20 again determines the relative positions of the observation markers associated to the different optical systems, following the method previously explained. So the equipment is of little dimension and can be easily stored when not in use.

[0072] Moreover, the equipment and the method described here can be generalized to any number of cameras referenced the ones with respect to the others. In this way, it is possible to measure the vehicle in different positions and at different heights.

Claiming

1. The optical equipment of determination of the relative positions of at least two objects (R) in space, of the type including at least two optical systems (12, 14, 16, 18) each associated to an observation marker (Cl2, C14, C16, C18), the optical systems being each adapted for the determination of an object in space with respect to its observation marker (Cl2, C14, C16, Cl8), from an image of the object recorded by the optical system (12, 14, 16, 18) characterized by the fact that the optical systems (12 ,14, 16, 18) are mobile ones compared to the others, that an optical system (12, 16), forming an optical system of reference, includes a set (26) of points of reference, of known geometrical configuration, the set (26) of points of reference being immobilized in a known position with respect to the observation marker (Cl2, C16) of the optical system of reference (12, 16), and visible from the or each other optical system (14, 16, 18) in the absence of the objects, by the fact that the or each other optical system (14, 16, 18) includes means (20) of analysis of an image of the set (26) of reference points and of the means (20) of positioning of the set (26) of reference points with respect to its observation marker (C14, C16, Cl8), that it includes means (20) of deduction of the position of the observation marker (C14, Cl6, Cl8) of the or each other optical system (14, 16, 18) with respect to observation marker (Cl2, C16) of the optical system of reference, from the position of the set (26) of points of reference with respect to each observation mark (C14, Cl6, Cl8), and of the known position of the set (26) of reference points with respect to the observation marker (Cl2, C16) of the optical system of reference (12, 16).

2. Equipment following claim 1, characterized by the fact that each optical system (12, 14, 16, 18) includes a video camera (12A, 14A, 16A, 18A) supported by a tripod (24) and connected to a common central data processing unit (20).

3. Equipment following claim 1 or 2, characterized by the fact that the aforesaid set (26) of points of reference includes a group of visible discreet coplanar markers (26A) as well as at least one visible non coplanar marker (26B).

4. Equipment following one of any of the previous claims, characterized by the fact that it includes brackets (60) adjusted to be joined each to an object (R) in a known position, and by the fact that each optical system (12, 14, 16, 18) includes means (20) of determination of a position of a bracket (60) in space with respect to its observation marker (Cl2, Cl4, Cl6, Cl8) and means (20) of deduction of the object's position (R) with respect to its observation marker (Cl2, Cl4, Cl6, Cl8)

from the determined position of the bracket (60) with respect to its observation marker (C12, C14, C16, C18) and to the known position of the bracket (60) with respect to its object (R).

5. Equipment including four optical systems (12, 14, 16, 18) intended to be set out sensibly on the vertex of a quadrilateral to determine the relative positions of four objects (R) in space, the objects (R) being set out on the inside of the area delimited by the quadrilateral, characterized by the fact that it includes two optical equipments (12, 14, 16, 18, 20) following one of any of the previous claims, the set (26) of points of reference of a first optical system of reference (12) being visible from the second optical system of reference (16) in the absence of objects (R), by the fact that the second optical system of reference (16) includes means (20) of analysis of an image of the set (26) of points of reference of the first optical system of reference (12) and means (20) of positioning of the set (26) of points of reference (12) with respect to its observation marker (C16), by the fact that it includes means (20) of deduction of the position of the observation marker (C16) of the second optical systems of reference (16) with respect to the observation marker (C12) of the first optical systems of reference (12), from the position of the set (26) of points of reference of the first optical systems (12) with respect to the observation marker (C16) of the second optical systems of reference (16), and of the known position of the set (26) of points of reference of the first optical systems of reference (12) with respect to the observation marker (C12) of the first optical systems of reference (12) by the fact that it includes means (20) of deduction of the relative position of the observation marker (C12, C14, C16, C18) of each optical systems (12, 14, 16, 18).

6.Optical method of determination of the relative positions of at least two objects (R) in space, of the type using at least two optical systems (12, 14, 16, 18) each associated to an observation marker (C12, C14, C16, C18), the optical systems being each adapted to determine the position of an object in space with respect to its observation marker (C12, C14, C16, C18), from an image of the object revealed by the aforesaid optical system (12, 14, 16, 18), characterized by the fact that the optical systems (12, 14, 16, 18) are mobile the ones compared to the others, the fact that an optical system (12, 16), forming on optical system of reference is equipped with a set (26) of points of reference, of known geometrical configuration, the set (26) of points of reference being immobilized in a known position with respect to the observation marker (C12, C16) of the optical systems of reference (12, 16), and visible from the or each other optical system (14, 16, 18) in the absence of objects (R), by the fact that the or each other optical system (14, 16, 18) analyses an image of the set (26) of the reference points and determines the positioning of the set (26) of the points of reference with respect to its observation marker (C14, C16, C18), and by the fact that the position of the observation marker (C14, C16, C18) is deduced from the or each other optical systems (14, 16, 18) with respect to the observation marker (C12, C16) of the optical systems of reference, from the position of the set

(26) of points of reference with respect to each observation marker (C14, C16, C18), and from the known position of the set (26) of points of reference with respect to the observation marker (C12, C16) of the optical system of reference (12, 16).

P13 - Chart

European research report

DOCUMENTS CONSIDERED AS BEING RELEVANT

Category	Document stating with indication, of the relevant parts	Concerned claim	Classification of needed application

Required technical Fields

This report has been established for all claims

Place of research	Date of completion of research	Examiner

Category of stated documents

X : particularly relevant in itself
Y : particularly relevant in combination with another document of the same category
A : Technological background
O : Non written disclosure
P : Interpolated document
T : Theory or basic principle of the invention
E :Document of previous patent, but published at the date of registration or after this date
D : Stated in the application
L : Stated for other reasons
....
& : part of the same group, corresponding document

R

P14 – Chart

Annex to the European research report related to the European patent application N° EP 99 40 2838

This annex indicates the members of the group of patents that are relative to the patent documents stated in the European research report stamped above.

The aforesaid members are held in the computer file of the European Office of patents on the following date : 14-01-2000

The data is handed as information and do not engage the responsibility of the European Office of patents.

For all information concerning this annex : See Official Journal Of the European Office of patents no. 12/82